DESCRIPTION

BLENDED WOVEN OR KNITTED FABRICS CONTAINING POLYURETHANE ELASTIC FIBERS AND PROCESS FOR THE PRODUCTION THEREOF

TECHNICAL FIELD

The present invention relates to woven or knit fabrics containing polyurethane elastic filaments in combination with other fibers, and to a process for manufacturing such fabrics. More specifically, the invention relates to polyurethane elastic filament-containing blended woven or knit fabrics, including circular knit (e.g., plain, rib, purl) and other types of weft knit fabrics, warp knit fabrics (e.g., chain, denbigh, cord, atlas), and woven fabrics, which minimize the appearance of fabric defects such as deformation, yarn slippage and grinning from repeated stretching when articles made from such woven or knit fabrics are worn, fraying in which threads are lost from cut edges of the fabric, damage or defects of the type known as laddering or running that arise in the fabric structure, edge curling of the fabric, and the effect sometimes referred to as "slip-in" where just the elastic filaments pull away from a seam in an article that has been cut and sewn, causing the fabric to lose its stretch in places. The invention relates also to a process for manufacturing such fabrics.

BACKGROUND ART

Articles made from stretch fabrics such as polyurethane elastic filament-containing blended fabrics that have been weft knitted, warp knitted or woven are widely used on account of their high stretch, good recovery from extension, and good fit. However, when an article made by cutting and sewing a polyurethane elastic filament-containing blended fabric is repeatedly stretched, it deforms, causing the fabric to lose its uniformity and making it subject to problems such as deformation, yarn slippage, grinning,

fraying, running and edge curling. In sewn areas, repeated extension also tends to cause polyurethane elastic filaments to pull away from the seams ("slip-in"). In an area of the fabric where such slip-in has occurred and elastic filaments have left from a seam, the loss of shrinkage force tends to give rise to places of uneven density in the fabric, which can render an item of apparel unfit for use.

While these effects do occur even in woven and knit goods made with elastic filaments other than polyurethane elastic filaments, they are especially striking in fabrics containing high-stretch polyurethane elastic filaments.

The following solutions have been proposed for these problems.

(1) Suppress the shrinkage force of the polyurethane elastic filaments.

(i) Avoid excessive extension of the polyurethane elastic filaments.

(ii) Increase the woven and knit fabric treatment temperature to hold down the shrinkage force of the polyurethane elastic filaments.

(iii) Select elastic filaments having a high heat settability.

(2) Fuse the polyurethane elastic filaments to each other at crossover points by increasing the heat-setting temperature.

(3) Prevent the above effects by using low-melting polyurethane elastic filaments and having them fuse at a low temperature.

(4) Increase the stitch density during sewing to prevent the polyurethane elastic filaments from sliding and thus discourage slip-in from occurring.

(5) If the polyurethane elastic filaments are used in the form of a covered yarn, give the yarn a high twist or a double-covered structure. The air entanglement of such a covered yarn with another yarn has also been proposed (see JP-A 4-11036).

(6) Employ a weaving or knitting technique that is resistant to slip-in and yarn slippage (see JP-A 2002-69804 and JP-A 2002-13052).

However, lowering the degree of extension of polyurethane elastic filaments as in (1)(i) above also lowers the stretch properties of the fabric and increases costs owing to the larger amount of polyurethane elastic filaments that is used as a result. Weakening the shrinkage force of the polyurethane elastic filaments by increasing the heat-setting temperature as in (1)(ii) above is undesirable because this changes the tactile qualities of the fibers with which the polyurethane elastic filaments are used and also lowers the colorfastness of the woven or knit fabric. In weft or warp knit fabrics where there are crossover points between the elastic filaments as in (2) above, problems such as edge curling and slip-in can be prevented by fusing the elastic filaments. However, because such fusion requires the fabric to be heat set at a high temperature, the tactile qualities of the fibers with which the polyurethane elastic filaments are used change and the colorfastness of the fabric decreases. Increasing the stitch density during sewing as in (4) above makes the sewn areas of the fabric thicker, as a result of which articles of apparel created from the fabric are less comfortable to wear and thus at odds with the demands of the market.

If elastic filaments that fuse at a low temperature are used as in (3) above, these filaments can be fused at a low heat-setting temperature of 140 to 160°C. However, when such filaments are used in combination with high-melting polyurethane elastic filaments, the latter do not set to a sufficient degree, as a result of which the fabric has a poor dimensional stability. On the other hand, if heat setting is carried out within a high temperature range at which the high-melting polyurethane elastic filaments can set properly, the elastic filaments which generally fuse at a low temperature will incur a large decline in strength, weakening the recovery of the fabric from extension. Also, methods

such as (4) and (5) above which involve the use of special composite yarns or a special knitting technique undesirably limit the properties of the finished article.

JP-A 2001-159052 describes a method for preventing yarn slippage by heat-treating at 200°C a woven or knit fabric made with two kinds of polyether ester elastic filament having different melting points. However, in terms of elastic recovery and strain, polyether ester elastic filaments have a performance inferior to that of polyurethane elastic filaments, and are thus unsatisfactory.

It is therefore an object of the present invention to provide polyurethane elastic filament-containing woven or knit fabrics which are stable and not subject to the loss of elastic filaments and non-elastic yarns used therein from cut and sewn areas of the fabric, and which are thus resistant to yarn slippage, grinning, fraying, running, edge curling and slip-in.

DISCLOSURE OF THE INVENTION

As a result of extensive investigations, we have discovered that when a blended woven or knit fabric which contains highly fusible polyurethane elastic filaments typically obtained by melt-spinning a polymer synthesized from a prepolymer prepared by the reaction of a polyol with a diisocyanate, wherein preferably at least 50 wt% of the starting polyol is a polyether polyol, and which contains also non-elastic yarns is heat-set, heat fusion occurs at places where the polyurethane elastic filaments come into contact with the non-elastic yarns and at places where the polyurethane elastic filaments come into contact with each other, giving a fabric that is resistant to yarn slippage, grinning, fraying, running, edge curling and slip-in without any loss in tenacity.

The present invention thus provides the following polyurethane elastic filament-containing blended woven or knit fabrics and processes for manufacturing such fabrics.

[I] A blended woven or knit fabric comprising

highly fusible polyurethane elastic filaments having at least 50% retention of tenacity after dry heat treatment at 150°C for 45 seconds at 100% extension and a melting point of 180°C or below and

at least one kind of non-elastic yarn,

said fabric being obtained by dry or wet heat setting so as to thermally fuse the highly fusible polyurethane elastic filaments to each other or to the non-elastic yarns, preferably to the non-elastic yarns, at crossover points therebetween.

[II] The blended woven or knit fabric of [I] further comprising high-melting polyurethane elastic filaments having a melting point of 200°C or higher,

said fabric being obtained by thermally fusing the highly fusible polyurethane elastic filaments with the high-melting polyurethane elastic filaments at crossover points therebetween.

[III] A process for manufacturing a blended woven or knit fabric containing polyurethane elastic filament comprising the steps of

forming a woven or knit fabric using highly fusible polyurethane elastic filaments having at least 50% retention of tenacity after dry heat treatment at 150°C for 45 seconds at 100% extension and a melting point of 180°C or below and at least one kind of non-elastic yarn and

dry or wet heat setting the woven or knit fabric so as to thermally fuse the highly fusible polyurethane elastic filaments to each other or to the non-elastic yarns, preferably to the non-elastic yarns, at crossover points therebetween.

[IV] The blended woven or knit fabric manufacturing process of [III] which additionally uses high-melting polyurethane elastic filaments having a melting point of 200°C or higher, and thermally fuses the highly fusible polyurethane elastic filaments with the high-melting polyurethane elastic filaments at crossover points therebetween.

BRIEF DESCRIPTION OF THE DIAGRAMS

FIG. 1 is a diagram showing an example of a chain knit fabric structure.

FIG. 2 is a point diagram of the same chain knit fabric structure.

FIG. 3 is a point diagram showing an example of a warp knit fabric structure.

FIG. 4 is a point diagram showing another example of a warp knit fabric structure.

FIG. 5 is a point diagram showing yet another example of a warp knit fabric structure.

FIG. 6 is a point diagram showing a further example of a warp knit fabric structure.

FIG. 7 is a point diagram showing a still further example of a warp knit fabric structure.

FIG. 8 is a point diagram showing yet another example of a warp knit fabric structure.

FIG. 9 is a point diagram showing a still further example of a warp knit fabric structure.

FIG. 10 shows a warp knit fabric specimen for a tensile test.

BEST MODE FOR CARRYING OUT THE INVENTION

The invention is described more fully below.

The polyurethane elastic filaments used in the invention, insofar as they are highly fusible polyurethane elastic filaments which readily fuse even at low temperature and exhibit heat resistance, are not subject to any particular limitations with regard to composition or method of production. Suitable methods of production include processes in which a polyol is reacted with an excess molar amount of diisocyanate to form a polyurethane intermediate polymer having isocyanates at both ends, the intermediate polymer is reacted in an inert organic solvent with a low-molecular-weight diamine or diol having active hydrogens capable of reacting with the isocyanate groups on the intermediate polymer so as to form a polyurethane solution

(polymer solution), then the solvent is removed and the polymer is shaped into filaments; processes in which a polymer formed by reacting a polyol and a diisocyanate with a low-molecular-weight diamine or diol is solidified, then dissolved in a solvent, after which the solvent is removed and the polymer is shaped into filaments; processes in which the above solidified polymer is heated and shaped into filaments without being dissolved in a solvent; processes in which the above polyol, diisocyanate and low-molecular-weight diol are reacted to form a polymer, which is then shaped into filaments without first being solidified; and processes in which polymers or polymer solutions obtained by the various above processes are mixed, following which the solvent is removed from the mixed polymer solution and the polymer is shaped into filaments. Of the above, a process in which (A) a prepolymer obtained by reacting a polyol with a diisocyanate and having isocyanate groups at both ends (referred to below as an "isocyanate-terminated prepolymer") is reacted with (B) a prepolymer obtained by reacting a polyol with a diisocyanate and a low-molecular-weight diol and having hydroxyl groups at both ends (referred to below as a "hydroxy-terminated prepolymer") is melt-spun without prior solidification is especially preferred because it gives highly fusible polyurethane elastic filaments which fuse easily at low temperature and are heat resistant. Moreover, such a process is cost-effective because it does not include the recovery of solvent.

The polyol used in prepolymers (A) and (B) may be the same or different. In both cases, the use of a polymer diol having a number-average molecular weight in a range of about 800 to 3,000 is preferred.

Such polymer diols that are suitable for use include polyether glycols, polyester glycols and polycarbonate glycols.

Illustrative examples of polyether glycols include polyether diols obtained by the ring-opening polymerization of a cyclic ether such as ethylene oxide, propylene oxide or

tetrahydrofuran; and polyether glycols obtained by the polycondensation of a glycol such as ethylene glycol, propylene glycol, 1,4-butanediol, 1,5-pentanediol, neopentyl glycol, 1,6-hexanediol and 3-methyl-1,5-pentanediol.

Illustrative examples of polyester glycols include polyester glycols obtained by the polycondensation of at least one glycol selected from among ethylene glycol, propylene glycol, 1,4-butanediol, 1,5-pentanediol, neopentyl glycol, 1,6-hexanediol and 3-methyl-1,5-pentanediol with at least one dibasic acid selected from among adipic acid, sebacic acid and azelaic acid; and polyester glycols obtained by the ring-opening polymerization of a lactone such as ε-caprolactone or valerolactone.

Illustrative examples of polycarbonate glycols include those obtained by the transesterification of at least one organic carbonate selected from among dialkyl carbonates such as dimethyl carbonate and diethyl carbonate, alkylene carbonates such as ethylene carbonate and propylene carbonate, and diaryl carbonates such as diphenyl carbonate and dinaphthyl carbonate, with at least one aliphatic diol selected from among ethylene glycol, propylene glycol, 1,4-butanediol, 1,5-pentanediol, neopentyl glycol, 1,6-hexanediol and 3-methyl-1,5-pentanediol.

The above polyether glycol, polyester glycol or polycarbonate glycol may be used singly or as combinations of two or more thereof. However, to obtain a good fusibility, it is desirable for the polyether diol component to account for at least 50 wt%, and preferably at least 60 wt%, of the total amount of polymer diol used. The polyether diol component may even account for 100 wt% of the polymer diol used. Polytetramethylene ether glycol is especially preferred as the polyether diol component.

The diisocyanate used in prepolymers (A) and (B) may be any type of diisocyanate commonly used in the production of polyurethanes, such as aliphatic, alicyclic, aromatic and aromatic-aliphatic diisocyanates.

Illustrative examples of such diisocyanates include 4,4'-diphenylmethane diisocyanate, 2,4-tolylene diisocyanate, 1,5-naphthalene diisocyanate, xylylene diisocyanate, hydrogenated xylylene diisocyanate, isophorone diisocyanate, 1,6-hexamethylene diisocyanate, p-phenylene diisocyanate, 4,4'-dicyclohexylmethane diisocyanate, m-tetramethylxylene diisocyanate and p-tetramethylxylene diisocyanate. Any one or combination thereof may be used. Of these, 4,4'-diphenylmethane diisocyanate and 4,4'-dicyclohexylmethane diisocyanate are preferred.

The low-molecular weight diol or low-molecular-weight diamine, which serves as a chain extender, is preferably one which has a suitable reaction rate and imparts an appropriate heat resistance. A low-molecular-weight compound with two active hydrogen atoms capable of reacting with isocyanate and generally having a molecular weight of 500 or less is used.

Suitable examples of such low-molecular-weight diols include aliphatic diols such as ethylene glycol, propylene glycol, 1,4-butanediol, 1,5-pentanediol, neopentyl glycol, 1,6-hexanediol, and 3-methyl-1,5-pentanediol. Trifunctional glycols such as glycerol can also be used provided the spinnability is not compromised. Any one or combination of two or more of these compounds may be used, although ethylene glycol and 1,4-butanediol are preferred for good workability and for imparting suitable properties to the resulting fibers.

Examples of low-molecular-weight diamines that may be used include ethylenediamine, butanediamine, propylenediamine, hexamethylenediamine, xylylenediamine, 4,4-diaminodiphenylmethane and hydrazine.

While it is possible to use both a low-molecular-weight diol and a low-molecular-weight diamine, the use of a low-molecular weight diol as the chain extender is preferable for achieving the purposes of the invention.

A monohydric alcohol such as butanol or a monoamine such as diethylamine or dibutylamine may be used in admixture to regulate the reaction or the degree of polymerization.

Illustrative examples of the inert solvent used during the polyurethane polymerization reaction or as the spinning solution include polar solvents such as N,N-dimethylformamide, N,N-dimethylacetamide, N,N,N',N'-tetramethylurea, N-methylpyrrolidone and dimethylsulfoxide.

The prepolymers serving as above components (A) and (B) may have added thereto optional ingredients such as ultraviolet absorbers, antioxidants and light stabilizers to improve weather resistance, heat and oxidation resistance and yellowing resistance.

Illustrative examples of ultraviolet absorbers include benzotriazole compounds such as 2-(3,5-di-t-amyl-2-hydroxyphenyl)benzotriazole, 2-(3-t-butyl-5-methyl-2-hydroxyphenyl)-5-chlorobenzotriazole and 2-(2-hydroxy-3,5-bisphenyl)benzotriazole.

Illustrative examples of antioxidants include hindered phenol antioxidants such as 3,9-bis(2-(3-(3-t-butyl-4-hydroxy-5-methylphenyl)propionyloxy)-1,1-dimethylethyl)-2,4,8,10-tetraoxaspiro[5.5]undecane, 1,3,5-tris(4-t-butyl-3-hydroxy-2,6-dimethylbenzyl)isocyanuric acid and pentaerythritol tetrakis[3-(3,5-di-t-butyl-4-hydroxyphenyl)-propionate].

Illustrative examples of light stabilizers include hindered amine light stabilizers such as bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate, bis(1,2,2,6,6-pentamethyl-4-piperidyl) sebacate, and the dimethyl-1-(2-hydroxyethyl)-4-hydroxy-2,2,6,6-tetramethyl-piperidine condensation product of succinic acid.

The process by which the polyurethane elastic filaments of the invention are obtained is not subject to any particular limitation. Examples of known melt spinning techniques that may be used include the following.

(1) Melt spinning from chips of polyurethane elastomer.

(2) A process in which chips of polyurethane elastomer are melted, a polyisocyanate compound is added, and spinning is carried out.

(3) A reaction spinning process that involves synthesizing a spinning polymer by reacting a prepolymer prepared from a polyol and a diisocyanate with a low-molecular-weight diol, then spinning the polymer without prior solidification.

Process (3) is preferred because it does not include a polyurethane elastomer chip handling step and is thus simpler than Processes (1) and (2). Also, in this process, by adjusting the proportion of prepolymer added to the reactor, the amount of residual isocyanate groups left in the polyurethane elastic filaments after spinning can be controlled, making it possible to achieve an improved heat resistance from chain extending reactions by these residual isocyanate groups. Moreover, in Process (3), as described in JP-A 11-839030, the low-molecular-weight diol can be reacted beforehand with some of the prepolymer to form a prepolymer having excess hydroxyl groups which is then added to the reactor.

It is especially preferable to obtain the polyurethane elastomer fibers of the invention by, according to Process (3), feeding prepolymers (A) and (B) continuously and at a constant rate to a reactor, and melt spinning the resulting polymer without prior solidification.

Synthesis of the spinning polymer in this way involves three reactions: (I) synthesis of an isocyanate-terminated prepolymer, (II) synthesis of a hydroxy-terminated prepolymer, and (III) synthesis of a polymer for spinning by feeding these two prepolymers to a reactor and continuous reaction. The compositional ratio of the starting materials for the three above reactions as a whole, when expressed as the ratio of the number of moles of all the diisocyanate to the combined number of moles of all the polymer diol and all the low-molecular-weight diol, is preferably from 1.02 to 1.20.

More specifically, the above isocyanate-terminated prepolymer (I) can be obtained by, for example, charging a given amount of diisocyanate into a tank equipped with a warm-water jacket and a stirrer, then adding a given amount of polymer diol under stirring, and stirring at 80°C for 1

hour under a nitrogen purge. The isocyanate-terminated prepolymer obtained from this reaction is then fed by a jacketed gear pump (e.g., KAP-1, manufactured by Kawasaki Heavy Industries, Ltd.) to a reactor for polyurethane elastic filament production.

The above hydroxy-terminated prepolymer (II) can be obtained by charging a given amount of diisocyanate into a tank equipped with a warm-water jacket and a stirrer, adding a given amount of polymer diol under stirring, then stirring at 80° C for 1 hour under a nitrogen purge to give a precursor, and subsequently adding a low-molecular-weight diol and reacting it with the precursor under stirring. The resulting hydroxy-terminated prepolymer is then fed by a jacketed gear pump (e.g., KAP-1, manufactured by Kawasaki Heavy Industries, Ltd.) to the reactor for polyurethane elastic filament production.

During the synthesis of these two prepolymers, the various chemicals mentioned above may be added to improve such properties as the weather resistance, heat and oxidation resistance, and yellowing resistance.

The spinning polymer (III) can be synthesized by continuously reacting prepolymers (A) and (B) fed to the reactor in fixed proportions. The reactor may be one commonly used in polyurethane elastic filament melt spinning processes and is preferably equipped with mechanisms for stirring and reacting the molten mixture, heating the spinning polymer, and transferring the polymer to a spinning head. Reaction is typically carried out at 160 to 220° C for 1 to 90 minutes, and preferably at 180 to 210° C for 3 to 80 minutes.

The polyurethane elastic filaments of the invention can be obtained by transferring the synthesized spinning polymer, without allowing it to solidify, to a spinning head, and spinning the polymer by discharging it from a nozzle. The average residence time of the spinning polymer within the reactor varies with the type of reactor, and is calculated as follows.

Average residence time in reactor =

[(reactor volume)/(discharge rate of spinning polymer)]

× (specific gravity of spinning polymer)

This is generally about one hour when a cylindrical reactor is used, and 5 to 10 minutes when a twin-screw extruder is used. The polyurethane elastic filament can be obtained by continuous extrusion from the nozzle at a spinning temperature of 180 to 230°C, followed by cooling, the application of a spin finish, and wind-up.

It is advantageous for the ratio between the isocyanate-terminated prepolymer and the hydroxy-terminated prepolymer to be set by suitably adjusting the speed ratio between the gear pumps used for injecting the feedstocks so that the amount of isocyanate groups remaining in the just-spun filaments is 0.3 to 1 wt%, and preferably 0.35 to 0.85 wt%. The presence of isocyanate groups in an excess of at least 0.3 wt% enables physical properties such as tenacity, elongation and heat resistance to be improved by chain extension reactions after spinning. By contrast, the presence of less than 0.3 wt% of isocyanate groups may lower the retention of tenacity under heating of the resulting polyurethane elastic filament, whereas the presence of more than 1 wt% may lower the viscosity of the spinning polymer and make spinning difficult to carry out.

The content of isocyanate groups in the spun filament is measured as follows.

About 1 gram of the spun filament is dissolved in a dibutylamine/dimethylformamide/toluene solution, following which excess dibutylamine is reacted with isocyanate groups in the sample. The remaining dibutylamine is then titrated with hydrochloric acid, based on which the content of isocyanate groups in the sample is determined.

It is especially preferable for the polyurethane elastic filament used in this invention to be produced as

described above by a melt-reaction spinning process using polyether diol as a primary starting material.

The polyurethane elastic filament used in the invention has at least 50%, and preferably at least 55%, retention of tenacity following dry heat treatment at 150°C for 45 seconds at 100% extension. At less than 50% retention of tenacity, the heat-set article will have reduced stretch.

There is no particular upper limit in the retention of tenacity, although it is generally 90% or less, and especially 80% or less.

The polyurethane elastic filament has a melting point of 180°C or less, and preferably 175°C or less. At a melting point above 180°C, the heat treatment temperature required for fusion is too high, adversely affecting such qualities of the textile product as its hand and colorfastness.

A melting point of at least 150°C, and preferably at least 155°C, is advantageous in terms of dimensional stability when the above filament is used in combination with a high-melting polyurethane elastic filament, and also in terms of the fabric's recovery from extension.

A method for measuring the retention of tenacity is described later in the specification.

The polyurethane elastic filament-containing blended woven or knit fabric of the invention may be a fabric having one of the following constructions obtained by using the above-described highly fusible polyurethane elastic filament in combination with a non-elastic yarn, and also incorporating, for example, a high-melting polyurethane elastic filament having a melting point of at least 200°C.

(1) Woven fabrics in which a composite yarn composed of the highly fusible polyurethane elastic filament and at least one type of non-elastic yarn are used as the warp yarns and/or filling yarns. The fabric may have, for example, a plain, twill or satin weave. The loom used to make the fabric may be, for example, a shuttle loom, a rapier loom or an air jet loom. The warp yarns and filling yarns may

all be such composite yarns, or composite yarns and non-elastic yarns may be used in combination at a fabric count ratio therebetween of, for example, 1:1, 1:2 or 1:3.

(2) Weft knit fabrics in which the highly fusible polyurethane elastic filament and at least one type of non-elastic yarn are used together in the same courses on a knitting machine. Weft knit fabrics constructed of the highly fusible polyurethane elastic filament and a non-elastic yarn can be knit using plain, rib, purl or interlock stitches, or may have a structure representing a combination or modification of any of these basic structures. Any weft knitting machine may be used, including circular knitting machines, flat knitting machines, full fashion machines and hosiery machines. The highly fusible polyurethane elastic filament may be either laid in or knit in. Alternatively, the highly fusible polyurethane elastic filament and the non-elastic yarn may be knit in a plated structure, or use may be made of a composite yarn composed of the highly fusible polyurethane elastic filament and the non-elastic yarn. As in (1) above, the highly fusible polyurethane elastic filament may be knit in at every course, or may be knit in at every other one or more course. The highly fusible polyurethane elastic filament and the non-elastic yarn may be knit in either in an alternating arrangement or at some other suitable interval therebetween. In addition, a high-melting polyurethane elastic filament may be incorporated. Several exemplary constructions of this type are listed below, although the possibilities are not limited solely to these.

(2)-1 All courses:

Feed 1: Highly fusible yarn and non-elastic yarn, or composite yarn

Feed 2: Highly fusible yarn and non-elastic yarn, or composite yarn

Feed 3: Highly fusible yarn and non-elastic yarn, or composite yarn

Feed 4: Highly fusible yarn and non-elastic yarn, or composite yarn

(2)-2 Every other course:

Feed 1: Highly fusible yarn and non-elastic yarn, or composite yarn

Feed 2: Non-elastic yarn

Feed 3: Highly fusible yarn and non-elastic yarn, or composite yarn

Feed 4: Non-elastic yarn

(2)-3 Highly fusible yarn and high-melting yarn used in every other course:

Feed 1: Highly fusible yarn and non-elastic yarn, or composite yarn

Feed 2: High-melting yarn and non-elastic yarn, or composite yarn

Feed 3: Highly fusible yarn and non-elastic yarn, or composite yarn

Feed 4: High-melting yarn and non-elastic yarn, or composite yarn

(2)-4 Alternating arrangement

Feed 1: Highly fusible yarn

Feed 2: Non-elastic yarn, or highly fusible yarn and non-elastic yarn

Feed 3: Highly fusible yarn

Feed 4: Non-elastic yarn, or highly fusible yarn and non-elastic yarn

(3) Warp knit fabrics in which the highly fusible polyurethane elastic filament and at least one type of non-elastic yarn are used in combination. Warp knit fabric structures incorporating the highly fusible polyurethane elastic filament and a non-elastic yarn can be knit using chain, denbigh, cord or atlas stitches, or may have a structure representing a combination or modification of any of these basic structures. Any warp knitting machine

may be used, including tricot machines, raschel machines, and milanese machines. As in (1) above, the highly fusible polyurethane elastic filaments may be knit in throughout the fabric, or may be knit in at suitable intervals. The highly fusible polyurethane elastic filaments may be either laid in or knit in. In addition, high-melting polyurethane elastic filaments may be incorporated. Several exemplary constructions of this type are described below, although the possibilities are not limited solely to these.

(3)-1 Knit fabric with chain structure

FIGS. 1 and 2 show a chain structure often used in lace and other fabric. Defects such as runs and ravels readily occur in this chain structure after cut edges have been sewn. Ladder-resist structures have been proposed as a solution, but signs of the ladder-resist structure remain visible in the fabric and spoil the sense of high quality. Referring to FIGS. 1 and 2, if (a) non-elastic yarns and (b) highly fusible polyurethane elastic filaments according to the invention or such highly fusible polyurethane elastic filaments doubled with high-melting polyurethane elastic filaments are knit in and heat set, the highly fusible polyurethane elastic filaments will contact and thermally fuse with the non-elastic yarn, and the highly fusible polyurethane elastic filaments will contact and thermally fuse with the high-melting polyurethane elastic filaments at the places denoted by **X** in FIG. 1, enabling a knit fabric to be obtained which has a good recovery from extension and prevents defects such as runs and ravels without a loss of aesthetic and other qualities.

(3)-2 Knit fabric with structures other than a chain structure

In other commonly used knit structures as well, when the highly fusible polyurethane elastic filaments of the invention are laid in or knit in, the fusion of these

filaments with non-elastic yarns and fusion of the polyurethane elastic filaments with each other discourages grinning (the shifting, loss or loosening of elastic filaments), enabling a substantial and dramatic improvement in the durability of the fabric. Moreover, because the fabric is more stable and edge curling is less likely to occur, costs during sewing operations can be expected to decrease.

For example, in the structures shown in FIGS. 3 to 8, the appropriate use of highly fusible polyurethane elastic filaments enables knit fabrics to be obtained which are resistant to yarn slippage, grinning, fraying, running, edge curling and slip-in.

In FIG. 3, guide bars L1 and L2 are fully threaded (All in). In FIG. 4, guide bars L1 and L2 and guide bars L3 and L4 are threaded at every other guide (1 in - 1 out). In FIGS. 5 to 8, guide bars L1, L2 and L3 are fully threaded (All in). In FIGS. 3 to 8, **a** represents a non-elastic yarn, and **b** represents the highly fusible polyurethane elastic filament of the invention either used alone or doubled with a high-melting polyurethane elastic filament. In FIGS. 5 and 6, **c** may represent the use of either two highly fusible polyurethane elastic filaments of the invention or the use of one highly fusible polyurethane elastic filament of the invention and one high-melting polyurethane elastic filament.

Moreover, depending on the particular application, in fabrics that are used without sewing up the cut edges, rubbing and chafing during laundering and wear have led until now to effects such as fraying that lower fabric durability. Large improvements can be made in this as well.

No particular limitation is imposed on the non-elastic yarn used together with the highly fusible polyurethane elastic filament. Illustrative examples include natural fibers such as cotton, linen, wool and silk; regenerated fibers such as rayon, cuprammonium rayon and polynosic; semi-synthetic fibers such as acetate; and synthetic fibers such

as nylon, polyester and acrylic. The polyurethane elastic filaments are included in a ratio of preferably about 1 to 40 wt%.

In the polyurethane elastic filament-containing blended woven or knit fabric of the invention, a woven or knit fabric that has a good elastic performance while remaining fusion property can be obtained by also incorporating high-melting polyurethane elastic filaments of excellent heat resistance and elastic recovery which have been dry-spun in a process involving a chain extension reaction with diamine and which melt at 200°C or more, and preferably at 210°C or more. The amount of such high-melting polyurethane elastic filaments used in this case is preferably about 2 to 40 wt%.

Dry heat setting can be carried out using a draft of hot air in a heat setting machine such as a pin tenter. This process is typically carried out at a temperature of 140 to 200°C, preferably 170 to 190°C, and for a period of 10 seconds to 3 minutes, preferably 30 seconds to 2 minutes.

Wet heat setting can be carried out by boarding the knitted article on a form in saturated steam at a predetermined pressure. This process is typically carried out at a temperature of 100 to 130°C, preferably 105 to 125°C, and for a period of typically 2 to 60 seconds, preferably 5 to 30 seconds.

The present invention enables polyurethane elastic filament-containing blended woven or knit fabrics to be obtained which can be treated at a low heat setting temperature and are resistant to such effects as yarn slippage, grinning, fraying, running, edge curling and slip-in.

EXAMPLE

The following examples and comparative examples, wherein all parts are by weight, are provided by way of illustration and not by way of limitation.

Example 1

The following isocyanate-terminated prepolymer and hydroxy-terminated prepolymer were prepared as the starting materials for the production of polyurethane elastic filaments.

Synthesis of Hydroxy-Terminated Prepolymer

A reactor sealed with nitrogen and equipped with a 80° C warm-water jacket was charged with 25 parts of 4,4'-diphenylmethane diisocyanate (MDI) as the diisocyanate, following which 100 parts of polytetramethylene ether glycol (PTMG) having a number-average molecular weight of 2,000 was added under stirring as the polymer diol. After one hour of reaction, 27.6 parts of 1,4-butanediol was added as the low-molecular-weight diol, thereby forming a hydroxy-terminated prepolymer.

Synthesis of Isocyanate-Terminated Prepolymer

A nitrogen-sealed 80° C reactor was charged with 47.4 parts of MDI as the diisocyanate and 2.2 parts of a mixture composed of an ultraviolet absorber (2-(3,5-di-t-amyl-2-hydroxyphenyl)benzotriazole: 20%), an antioxidant (3,9-bis(2-(3-(3-t-butyl-4-hydroxy-5-methylphenyl)propionyloxy)-1,1-dimethylethyl)-2,4,8,10-tetraoxaspiro[5.5]undecane: 50%) and a light stabilizer (bis(2,2,6,6-tetramethyl-4-piperidyl) sebacate: 30%), following which 100 parts of PTMG having a number-average molecular weight of 2,000 was added under stirring as the polymer diol. Stirring was continued for one hour, thereby giving an isocyanate-terminated prepolymer.

The resulting isocyanate-terminated prepolymer and hydroxy-terminated prepolymer were continuously fed in a weight ratio of 1:0.475 to a 2,200 ml cylindrical reactor for polyurethane elastic filament production equipped with a stirring element. The feed rates were 28.93 g/min for the isocyanate-terminated prepolymer and 13.74 g/min for the hydroxy-terminated prepolymer. The average retention time within the reactor was about 1 hour, and the reaction temperature was about 190° C.

The resulting polymer was fed without solidification to two 8-nozzle spinning heads held at 192° C. The spinning polymer was metered and pressurized by gear pumps mounted on the heads, then passed through a filter, discharged from 0.6 mm diameter single-hole nozzles at a rate per nozzle of 2.67 g/min into a 6 m long spinning chimney (total discharge rate from all nozzles, 42.67 g/min), and wound up at a speed of 600 m/min while having a finish applied thereto, giving 44-decitex polyurethane elastic filaments.

The polyurethane elastic filament immediately after discharge had an isocyanate group content of 0.42 wt%. The physical properties of the elastic filament was measured by the methods described below. The filament had a melting point of 168° C and 65% retention of tenacity under heating. The elastic filament was used to produce knit fabrics as described below. The unraveling tension of the fabric after it had been heat set was measured. The results are shown in Table 1.

Melting Point Measurement

Measuring apparatus: Thermomechanical analyzer (TMA), with quartz probe

Clamp interval: 20 mm

Extension: 0.5%

Temperature range: room temperature to 250° C

Temperature rise rate: 20° C/min

Determination: The melting point was defined as the temperature at which the thermal stress became 0 mgf.

Measurement of Tenacity Retention Under Heating

A polyurethane elastic filament was gripped at a clamp interval of 10 cm and extended to 20 cm. In this extended state, the filament was placed for 45 seconds in a hot air dryer held at 150° C and heat treated. The tenacity of this heat-treated polyurethane elastic filament was then measured using a constant-rate-of-extension tensile testing machine at a clamp interval of 5 cm and a rate of extension of 500 mm/min. Measurement was carried out at an ambient temperature of 20° C and 65% relative humidity.

Production of Knitted Fabric

Combination knitting was carried out by feeding 13 dtex, 7 filament nylon-6 yarns to feeders 2 and 4, and polyurethane elastic filaments to feeders 1 and 3 on a pantyhose knitting machine (manufactured by Lonati S.p.A., 400 needles).

Heat Setting

The knitted fabric was dry heat treated for 1 minute in a dryer held at 160° C or 180° C.

Measurement of Unraveling Tension

The unraveling tensions of the nylon yarn and the polyurethane elastic filament from the knit fabric were measured. The unraveling speed was set at 100 mm/min, and the average tension over a one minute period was determined.

Example 2

Aside from using polyethylene glycol adipate having a number-average molecular weight of 2,000 instead of PTMG, polyurethane elastic filament made with polyester diol was obtained in the same way as in Example 1. The isocyanate group content of the polyurethane elastic filament immediately after discharge from the spinneret was 0.45 wt%. Measurement of the physical properties carried out as in Example 1 showed that the resulting 44-dtex polyurethane elastic filament had a melting point of 170° C and 62% retention of tenacity under heating.

Using the elastic filament, a knitted fabric was produced in the same way as in Example 1. The unraveling tension of the knitted fabric after it had been heat set was measured. The results are shown in Table 1.

Comparative Example 1

A 44-dtex polyurethane elastic filament (Mobilon P type yarn, manufactured by Nisshinbo Industries, Inc.) made with PTMG as the polymer diol and a diamine as the chain extender was used. Measurement of the physical properties carried out as in Example 1 showed that these polyurethane

elastic filament had a melting point of 221°C and 95% retention of tenacity under heating.

Using the elastic filament, a knitted fabric was produced in the same way as in Example 1. The unraveling tension of the knitted fabric after it had been heat set was measured. The results are shown in Table 1.

Comparative Example 2

A spinning polymer was synthesized by the same method as in Example 1, extruded from the reactor through a 4 mm diameter orifice as a strand, cooled, then cut so as to give polyurethane elastomer pellets. The pellets were dried in a vacuum dryer, then re-melted in a single-screw extruder, metered and pressurized with a gear pump mounted on the spinning head as in Example 1 and passed through a filter, then discharged from 0.6 mm single-hole nozzles at a rate per nozzle of 2.67 g/min into a 6 meter long spinning chimney (total discharge from all nozzles, 42.67 g/min) and wound up at a speed of 600 m/min while having a finish applied thereto, giving 44-decitex polyurethane elastic filament. The polyurethane elastic filament immediately after discharge had an isocyanate group content of 0.13 wt%.

Measurement of the properties carried out as in Example 1 showed that the polyurethane elastic filament had a melting point of 152°C and 38% retention of tenacity under heating. Using the elastic filament, a knitted fabric was produced in the same way as in Example 1. The unraveling tension of the knitted fabric after it had been heat set was measured. The results are shown in Table 1.

Table 1

Unraveling tension from knitted fabric (cN)

Unraveled fiber	Nylon yarn		Polyurethane elastic filament	
Setting temperature	160° C	180° C	160° C	180° C
Example 1	1.0	6.3	1.5	3.2
Example 2	0.5	1.1	0.5	1.1
Comparative Example 1	0.1	0.5	0.0	0.4
Comparative Example 2	1.1	Not measurable because polyurethane elastic filament broke within knit fabric	1.6	Not measurable because polyurethane elastic filament broke within knit fabric

In Examples 1 and 2 according to the invention, the unraveling tension was high on account of fusion. The polyurethane elastic filament made with polyether diol in Example 1 had a particularly high unraveling tension. Moreover, in Examples 1 and 2, these elastic filaments within the knit fabric did not break even when the fabric had been heat set at 180° C. When the elastic filament was used together with high-melting polyurethane elastic filament in Comparative Example 1, fusion did not readily occur. In Comparative Example 2, the knit fabric had a high unraveling tension after being heat set at 160° C, but polyurethane elastic filament breakage occurred within the fabric when heat setting was carried out at 180° C.

Example 3

A knit fabric produced by the method described below using the polyurethane elastic filament obtained in Example 1 was heat set, then subjected to a laundering test, following which the fabric was visually inspected for fraying, slip-in and the surface properties. The results are shown in Table 2.

Production of Knit Fabric

A knit fabric having a plated structure was produced by feeding false-twisted Z-twist 33 dtex, 10 filament nylon-6 yarn to yarn feeders 1 and 3, feeding false-twisted S-twist 33 dtex, 10 filament nylon-6 yarn to feeders 2 and 4, and also feeding polyurethane elastic filaments to all four feeders on a pantyhose knitting machine (Lonati, 400 needles). The knit-in ratio was set at 2.5.

Heat Setting

The knitted fabric was dry heat treated for 1 minute in a dryer held at 180° C.

Laundering Test

Specimens measuring 15 × 20 cm were cut from the knit fabric after it had been heat set. The specimens were repeatedly washed (20 wash cycles) in a laundering test machine (LM-160, produced by Suga Test Instruments Co., Ltd.).

Amount of washing solution: 150 ml
Number of steel balls used: 10
Temperature: 50° C
Time: 30 min/cycle

Evaluation

Fraying: Fabric edges cut parallel to the course direction of the fabric were examined.

Slip-in: Fabric edges cut in the wale direction were examined, and the number of elastic filaments that slipped inward at least 5 mm from the edge of the fabric was determined as a percentage.

Yarn slippage: The degree of fabric smoothness was examined.

Edge curling: The edges of the fabric were examined.

Example 4

A knit fabric was produced on the same knitting machine and in the same way as in Example 3 by feeding the polyurethane elastic filaments of Example 1 to yarn feeders 1 and 3, and the elastic filaments of Comparative Example 1 to

feeders 2 and 4. The fabric was then subjected to the same tests as in Example 3. The results are presented in Table 2.

Comparative Example 3

A knit fabric was produced as in Example 3 using only the elastic filament of Comparative Example 1, and was tested in the same way. The results are shown in Table 2.

Comparative Example 4

A knit fabric was produced as in Example 3 using only the elastic filament of Comparative Example 2, and was tested in the same way. The results are shown in Table 2.

Table 2

Results of Knit Fabric Inspection

	Fraying	Slip-in (%)	Yarn slippage	Curling
Example 3	no	0	smooth	no
Example 4	no	5	smooth	no
Comparative Example 3	yes	55	surface uneven	slight curling
Comparative Example 4	no	0	surface uneven	no

In Comparative example 4, breakage of the polyurethane elastic filaments occurred in the fabric.

Example 5

Polyurethane elastic filament (156 dtex) was obtained by the same method as in Example 1. Measurement of the physical properties as in Example 1 revealed that this filament had a melting point of 170° C and 68% retention of tenacity under heating. This elastic filament was used to produce a warp knit fabric by the method described below. The fabric was then heat set, following which the resistance to pullout of the polyurethane elastic filament was measured. The results are shown in Table 3.

Fabric Production

A warp knit fabric was produced on a raschel knitting machine (manufactured by Karl Mayer GmbH, 28 gauge) using a 56 dtex, 17 filament nylon-6 yarn as yarn a on guide bar L1 and yarn c on guide bar L3 in FIG. 9, and using the above polyurethane elastic filament as yarn b on guide bar L2.

Heat Setting

The knitted fabric was dry heat treated for 1 minute in a dryer held at 190° C.

Measurement of Filament Pullout Resistance

Test specimens measuring 25 mm in the filling direction (width) by 100 mm in the warp direction (length), as shown in FIG. 10, were taken from the above knit fabric. A total of 10 specimens were collected, five for pullout of the polyurethane elastic filament from the end knitted first and five for pullout from the end knitted last.

Next, the test specimens were prepared as shown in FIG. 10. Each test specimen was cut away at a position (B-B') 40 mm from the lower end (D-D') so as to leave a single polyurethane elastic filament 1 inserted in the warp direction. Next, this remaining polyurethane elastic filament was freed from a 5 mm portion (E-F) of the fabric in the direction of an upper clamp 2. In addition, a 3 mm long slit 3 was made in the filling direction at a position 30 mm from the upper end of the specimen on a linear extension of the polyurethane elastic filament.

To measure the pullout resistance with a tensile testing machine, the testing machine clamp interval was adjusted to 40 mm, following which the top of the test specimen was gripped by the upper clamp 2 over a clamping length of 25 mm (the portion above A-A') and an initial load of 0.1 cN was applied to the polyurethane elastic filament. The polyurethane elastic filament was then gripped with a lower clamp 4 over a clamping length of 35 mm (the portion below C-C'), pulled at a rate of 100 mm/min, and the maximum pulling load up until the filament completely pulled out of the fabric was measured. This test was carried out a total

of ten times, five times from the end knitted first and five times from the end knitted last, and the average of these results was calculated, thereby giving the pullout resistance.

Comparative Example 5

Aside from using a 156 dtex polyurethane elastic filament obtained with PTMG as the polymer diol and a diamine as the chain extender (Mobilon P type yarn; Nisshinbo Industries, Ltd.; melting point, 217°C; 93% retention of tenacity under heating) as the yarn **b** inserted by guide bar L2 in FIG. 9, a warp knit fabric was produced in the same way as in Example 5. After heat setting, the pullout resistance of thread **b** inserted by guide bar L2 was measured. The results are shown in Table 3.

Example 6

A warp knit fabric was produced on the same type of knitting machine as in Example 5 using a 56 dtex, 17 filament nylon-6 yarn as yarn **a** on guide bar L1 in FIG. 3 and using the polyurethane elastic filament of Example 5 as yarn **b** on guide bar L2. The fabric was tested in the same way as in Example 5. The results are given in Table 3.

Comparative Example 6

Aside from using the same type of elastic filament as in Comparative Example 5 as yarn **b** on guide bar L2, a warp knit fabric was produced in the same way as in Example 6, following which the fabric was similarly tested. The results are given in Table 3.

Example 7

A warp knit fabric was produced on the same type of knitting machine as in Example 5 using 56 dtex, 17 filament nylon-6 yarn as the **a** yarns on guide bars L1 and L2 in FIG. 4 and using the polyurethane elastic filaments of Example 5 as the **b** yarns on guide bars L3 and L4. The fabric was tested

in the same way as in Example 5. The results are given in Table 3.

Comparative Example 7

Aside from using the elastic filaments of Comparative Example 5 as the b yarns on guide bars L3 and L4 in FIG. 4, a warp knit fabric was produced in the same way as in Example 7, following which the fabric was similarly tested. The results are given in Table 3.

Table 3

Results of pullout resistance test

	Pullout resistance (cN)
Example 5	56.8
Comparative Example 5	20.5
Example 6	could not be pulled out
Comparative Example 6	29.8
Example 7	52.5
Comparative Example 7	17.8

In Example 5 and 7 according to the invention, the pullout resistance was high due to fusion. In Example 6, fusion was of a degree that the filament could not be pulled out. Hence, fabrics resistant to yarn slippage and grinning were obtained. Combination with high-melting polyurethane elastic filaments in Comparative Examples 5, 6 and 7 discouraged fusion, resulting in a low pullout resistance. Yarn slippage and grinning occurred in these latter cases.

Example 8

A knit fabric was produced by the method described below and heat set, following which the unraveling tension of the fabric was measured, the state of fusion between polyurethane elastic filaments was checked, and fabric damage

from laundering tests (laundering durability) was visually evaluated. The results are given in Table 4.

Production of Knit Fabric

A knit fabric of the structure shown in FIG. 5 was produced on a raschel machine (Karl Mayer GmbH, 28 gauge). A warp knit fabric was made in the form of main pieces of fabric using a 56 dtex, 17 filament nylon-6 yarn as yarn a on guide bar L1 in FIG. 5, using the elastic filament of Comparative Example 5 as yarn c on guide bar L2, and using the polyurethane elastic filament of Example 1 as yarn c on guide bar L3. In addition, 110 dtex, 24 filament nylon yarn was used as draw threads between the main pieces of fabric to create the warp knit fabric.

Heat Setting

The knitted fabric was dry heat treated for 1 minute in a dryer held at 190° C.

Measurement of Unraveling Tension

The unraveling tension of the nylon yarn used as the draw threads was measured. The unraveling speed was set at 100 mm/min, the unraveling tension was measured over a one minute period, and the average of five peak values was determined.

Examination of Fused State

The nylon yarn in the main fabric pieces was dissolved with 20% dilute hydrochloric acid, and the fused state at points of contact between the polyurethane elastic filaments was examined.

Preparation of Specimen for Evaluation of Fabric Damage

A sample strip measuring 3.3 cm long in the knitting direction and 24.0 cm wide was cut from the heat-set fabric. A cut was made in the fabric from the widthwise edge of the strip at an angle of 40° to the knitting direction, separating the fabric into a "first knitted side" and a "last knitted side," then the cut edges of the strip in the knitting direction were joined together and sewn with an overlock sewing machine to form an annular specimen.

Laundering of Specimen for Evaluation of Fabric Damage

The prepared specimen was laundered continuously for 300 minutes under the following conditions.

Washing machine: Two-tub household washing machine

Amount of detergent: Adjusted to 1.3 g/L (used weakly alkaline detergent)

Amount of water: 30 L

Loading fabric: 1.0 kg of bare, plain knit fabric made with a combination of cotton and polyurethane elastic filament

Evaluation of Fabric Damage

The degree of damage to the cut edges on the "first knitted side" and the "last knitted side" were examined and rated according to the following criteria.

None: No apparent damage

Minimal: Slight degree of damage observable

Substantial: Significant degree of damage

Severe: Severe damage

Ratings of "Substantial" or "Severe" indicate a degree of damage that would make one hesitate to wear the item if it were an article of apparel. Ratings of "None" or "Minimal" indicate good durability to laundering.

Comparative Example 8

Aside from using the elastic filament of Comparative Example 1 as yarn c on guide bar L3 in FIG. 5, a warp knit fabric was produced in the same way as in Example 8. After the fabric was heat set, the unraveling tension of the draw thread was measured, the fused state of the polyurethane elastic filaments was checked, and the same tests as in Example 8 were carried out. The results are shown in Table 4.

Example 9

A warp knit fabric was produced on the same type of knitting machine as in Example 8 using a 56 dtex, 17 filament nylon-6 yarn as yarn a on guide bar L1 in FIG. 6, using the polyurethane elastic filament of Comparative Example 1 as

yarn c on guide bar L2, and using the polyurethane elastic filament of Example 1 as yarn c on guide bar L3. The fabric was tested in the same way as in Example 8. The results are given in Table 4.

Comparative Example 9

Aside from using the elastic filament of Comparative Example 1 as yarn c on guide bar L3 in FIG. 6, a warp knit fabric was produced in the same way as in Example 9, following which the fabric was similarly tested. The results are given in Table 4.

Example 10

A warp knit fabric was produced on the same type of knitting machine as in Example 8 using a 56 dtex, 17 filament nylon-6 yarn as yarn a on guide bar L1 in FIG. 7, using the polyurethane elastic filament of Example 1 as yarn b on guide bar L2, and using no draw threads. The fabric was tested in the same way as in Example 8. The results are given in Table 4.

Comparative Example 10

Aside from using the elastic filament of Comparative Example 1 as yarn b on guide bar L2 in FIG. 7, a warp knit fabric was produced in the same way as in Example 10, following which the fabric was similarly tested. The results are given in Table 4.

Example 11

A warp knit fabric was produced on the same type of knitting machine as in Example 8 using a 56 dtex, 17 filament nylon-6 yarn as yarn a on guide bar L1 in FIG. 8, using the polyurethane elastic filament of Example 1 as yarn b on guide bar L2, and using no draw threads. The fabric was tested in the same way as in Example 8. The results are given in Table 4.

Comparative Example 11

Aside from using the elastic filament of Comparative Example 1 as yarn b on guide bar L2 in FIG. 8, a warp knit fabric was produced in the same way as in Example 11, following which the fabric was similarly tested. The results are given in Table 4.

Table 4

Results for unraveling tension test, evaluation of fused state between elastic filaments, and evaluation of damage to cut edges of fabric

	Unraveling tension (cN)	Fused state between elastic filaments	Evaluation of damage/fraying at cut edges	
			First knitted side	Last knitted side
Example 8	18.6	Could not be separated: high fusibility	minimal	minimal
Comparative Example 8	7.2	Separated: low fusibility	severe	severe
Example 9	12.0	Could not be separated: high fusibility	minimal	minimal
Comparative Example 9	4.8	Separated: low fusibility	moderate	moderate
Example 10	--	Could not be separated: high fusibility	minimal	minimal
Comparative Example 10	--	Separated: low fusibility	severe	severe
Example 11	--	Could not be separated: high fusibility	none	minimal
Comparative Example 11	--	Separated: low fusibility	moderate	moderate

In Examples 8 and 9 according to the invention, the draw thread unraveling tension was high, indicating that the draw thread and the highly fusible polyurethane elastic filaments had strongly fused with each other. In Comparative Examples 8 and 9, the draw thread unraveling tension was low, indicating that fusion with the high-melting polyurethane elastic filaments did not readily occur. Concerning the state of fusion between the polyurethane elastic filaments,

in Examples 8 and 9 according to the invention, the highly fusible polyurethane elastic filaments fused completely with the high-melting polyurethane elastic filaments; points of contact between these filaments could not be separated by pulling. In Comparative Examples 8 and 9, fusion between high-melting polyurethane elastic filaments was weak; places of contact between these filaments separated when pulled. In Examples 10 and 11 according to the invention, the highly fusible polyurethane elastic filaments fused completely with each other; the fused places could not be separated by pulling. In Comparative Examples 10 and 11, fusion between the high-melting polyurethane elastic filaments was weak, allowing separation to occur.

In Examples 8, 9, 10 and 11 according to the invention in which highly fusible polyurethane elastic filaments were used and thermal fusion proceeded well, the degree of damage to the fabric from laundering at cut edges on both the "first knitted side" and "last knitted side" was rated as "None" or "Minimal," indicating a good durability to laundering. In Comparative Examples 8, 9, 10 and 11 in which high-melting polyurethane elastic filaments were used and thermal fusion was weak, the degree of damage to the fabric at cut edges on both the "first knitted side" and the "last knitted side" was rated as either "Substantial" or "Severe." In these cases, the damage that occurred was of a degree that would make one hesitate to wear the item if it were an article of apparel, indicating undesirable results.

Even in chain structures or commonly used structures other than chain structures which contain inserted or knit-in elastic filaments, by using the highly fusible polyurethane elastic filament of the invention, fusion with non-elastic yarns and fusion between polyurethane elastic filaments discourages yarn slippage, grinning, fraying, running, edge curling and slip-in, thus substantially and dramatically improving the durability of the fabric. Moreover, such fabrics are resistant to fraying and damage at cut edges thereon, even when laundered.